A SHORT DESCRIPTION

OF THE

BOSTON WATER-WORKS

DAM NO. 4.

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OF THE

BOSTON WATER-WORKS

BY

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SHORT DESCRIPTION OF THE BOSTON WATER WORKS.

SOURCES OF SUPPLY.

Cochituate. — The Sudbury and Cochituate supplies come from territory situated from seventeen to thirty-four miles west of Boston, on both sides of the line of the Boston & Albany Railroad. Water from Lake Cochituate, obtained by gravity, was introduced in 1848. The Cochituate aqueduct and the Brookline reservoir were the principal works constructed at that time, and are still in use. The watershed of Lake Cochituate, nineteen square miles, includes the greater part of the town of Natick and portions of adjacent towns. Chestnut Hill reservoir, about five miles west of the City Hall, was added to the works in 1870, to provide a large body of water close to the city in case of accident to the aqueduct.

Sudbury. — In 1872 it was found necessary to increase the supply of water, and an Act of the Legislature was obtained for an additional supply from Sudbury river. The permanent works were begun in 1873 and went into service in 1878. Including what has been subsequently added, they consist chiefly of a succession of reservoirs made by damming the river and its tributaries, and of an aqueduct from Sudbury river, near Framingham Centre, to Chestnut Hill reservoir. To satisfy pressing needs in 1872 and in 1875–8, before the permanent works were completed, the Sudbury water was turned into Lake Cochituate by means of a temporary dam on the river and a short ditch connecting with Beaver-dam brook, a feeder of the lake. The Sudbury

water-shed, seventy-five square miles, is four times as large as that of Lake Cochituate, and includes the whole of the town of Southborough and large portions of the surrounding towns. It is mostly hilly and much of it is rocky, but about nine per cent. of it is swampy ground. In 1895 the portion of the supply that is drawn from Sudbury river is about twice as great as that drawn from Lake Cochituate; but with further proposed developments the proportion will ultimately be about three to one. Annexations of towns[1] adjacent to old Boston have added to the city much elevated territory to which the water has to be raised by pumping. The supply comes to Chestnut Hill reservoir by gravity, but from that point an increasing proportion of it is pumped for the high service.

Mystic. — At the time of annexation, Charlestown already had a water-supply from Mystic lake, about six miles north of Boston. From this lake the water is pumped to a reservoir on Walnut Hill. The Mystic works in 1876 came under the control of the Boston Water Board, and are used to supply Charlestown and the neighboring municipalities of Chelsea, Somerville, and Everett. They supplied East Boston at intervals between 1870 and 1876, and they continued to supply Charlestown for many years. In 1894 the Sudbury and Cochituate water was connected with Charlestown, and has been turned into that portion of the city at various times. The Mystic water is of such poor quality that the abandonment of the supply has been recommended.

Capacity.—The quantity which the several water-sheds can be depended upon to furnish is determined from the minimum yield in the periods of severest drought found

[1] Roxbury was annexed to Boston in January, 1868.
Dorchester " " " " 1870.
Brighton " " " " 1874.
West Roxbury " " " " "
Charlestown " " " " "

in many years, taken in connection with the available storage capacity. It is as follows:

Sudbury . . .	56.4	millions U.S. gals. per day.
Cochituate . .	9.0	" " " " "
Mystic . . .	7.0	" " " " "

As the Sudbury and Cochituate are connected, and the surplus yield of the former may be stored in the latter, their combined supplies yield 66.4 millions U.S. gals. per day.

It is estimated that the present works, excluding the Mystic, will suffice for the supply of Boston till about 1899, when the population within the present city limits may be 550,000.

Comparison of the Supplies.

	Water-shed, sq. miles.	Date of construction.	Daily consumption U.S. gals., 1894.	Per capita consumption, 1894.
Cochituate .	18.87	1848	46,560,000	99.8
Sudbury .	75.20	1878		
Mystic . .	26.90	1864	10,282,100	87.6

The Sudbury and Cochituate works will be described together, and the Mystic works separately.

STORAGE RESERVOIRS.

Lake Cochituate is a natural pond or chain of ponds stretching more than three miles northward from the Boston & Albany Railroad, at Natick, eighteen miles west of Boston. It has an area of 785 acres. Its original capacity had been greatly increased by a mill-dam at the outlet before it was taken by Boston, but this dam was raised so as to give the lake a capacity of nearly 2,000,000,000 U.S. gallons above the level of the bottom of the aqueduct. In 1859 the lake was further raised 2 feet, and the capacity above the bottom of the aqueduct increased to 2,447,000,000 U.S. gallons.

As a slight supplement to the storage capacity of the lake, Dudley pond, 81 acres, was connected with it in 1862 by means of an 18-inch iron pipe about 800 feet long. The storage capacity of Dudley pond is 250,000,000 U.S. gallons; but its drainage area is insignificant. Its natural outlet was into Sudbury river below that of Lake Cochituate.

Dug pond, 44½ acres, another tributary of the lake, has been taken from Boston by Natick for its water-supply under Act of the Legislature. It immediately adjoins the lake at its southern end.

The Pegan Filter-Beds are on the borders of the lake adjacent to the Boston & Albany Railroad and at the mouth of Pegan brook. They were constructed in 1893 as a protection to the purity of the water of the lake from possible contamination by the brook, which flows through the thickly settled part of Natick. A dam was built across the mouth of the brook, and the ordinary flow of the stream as it accumulates behind the dam is raised a few feet by pumping upon natural sand filter-beds at three slightly different levels, having a total area of 4 acres. The soil was removed and made into embankments around and between the beds.

The Sudbury Storage Reservoirs are artificial basins formed by constructing large dams at favorable points across the valleys. The positions of the several reservoirs are shown on the accompanying map.

Dam No. 1 is on Sudbury river just below the confluence of the north fork, called Stony brook, with the south fork or main stream. It backs the water to Dam No. 3 and Dam No. 2, which are about a mile upstream in the valleys of Stony brook and the south fork respectively, odd numbers being assigned to the reservoirs in the former valley and even to those of the latter. These three dams are accessible from Framingham Centre. Reservoirs Nos. 1, 2, and 3 have in effect a continuous water surface of a crescent

shape, but their gate-chambers and pipes are arranged to keep them independent; the water from either No. 2 or 3 can be sent through the Sudbury aqueduct to Boston or wasted into the river without going into No. 1. Below Dam No. 1, Sudbury river flows in a north-easterly direction and unites with the Assabet to form the Concord river, which empties into the Merrimac at Lowell.

Reservoir No. 4, Reservoir No. 6, and Whitehall reservoir are each upon one of the three principal tributaries of the main stream, all coming from the south. They lie a mile or two south of the Boston & Albany Railroad. The water from these three reservoirs flows through Reservoir No. 2.

Reservoir No. 5 is on Stony brook just above the head of Reservoir No. 3. It is under construction (in 1895), occupying with its surrounding margin of land three square miles, mostly in Southborough but partly in Marlborough. The water from Reservoir No. 5 is to flow through Reservoir No. 3.

All the waterways are designed to discharge continuously 6 inches of rainfall collected on the water-sheds in 24 hours.

The datum plane of all the Boston Water Works levels or grades is tide marsh level or approximately mean high water.

The principal dimensions of the Sudbury dams and reservoir, are exhibited in the accompanying table.

	Length.		Drainage Area above Outlet.	Area of Water Surface.	Available Capacity.	Maximum Depth of Water.	Total Height Dam.	Elevation above Tide Marsh Level.			
	Dam. Feet.	Overfall. Feet.	Sq. Miles.	Acres.	Million U S. Gallons.	Feet.	Feet.	Earth Embankment.	High Water.	Tops of Flashboards.	Stone Crest.
Lake Cochituate	125	62.00	18.87	785	1,509	70	18	138.36	134.36	.....	132.36
Farm Pond	No. 1, 1130 No. 2, 195	Gate "	0.54	159	160	12	12	154.00	149.25		
Reservoir No. 1	786	168.67	74.66	143	280	14	23	166.80	161.00	159.29	157.54
Reservoir No. 3	3,506	100.51	27.68	253	1,080	21	32	181.32	177.00	None	175.24
Reservoir No. 5	1,950	300.00	22.28	1,220	7,400	67	74	256.00	250.00	250.00	[1] 249.00
Reservoir No. 2	1,340	184.67	45.14	134	530	17	25	173.83	168.00	167.12	165.87
Reservoir No. 4	1,857	30.00	6.43	167	1,400	49	60	221.00	215.21	215.21	214.21
Reservoir No. 6	1,540	30.00	5.86	185	1,530	55	65	301.00	295.00	295.00	294.00
Whitehall Reservoir (projected)	318	40.00	4.35	686	3,000	18	30	341.50	[2] 335.91	335.91	334.91
Mystic Lake	1,560	54.00	27.7	200	380	87	11	11.00	7.00		

[1] Projected. Bottom of foundation, 161.50.
[2] " The present high water is 327.91.

Reservoir No. 1. — Dam No. 1 forming this reservoir is founded on gravel and sand. It has a masonry overfall with a gate-house at one end and earth embankments at both ends. The overfall is of substantial masonry 15 feet high above the apron and 168.67 feet long. The crest is 9.26 feet below the top of the dam. Against the up-stream side of the masonry there is an earth embankment, the toe of which is protected by sheet piling. Below the overfall is an apron of heavy stones laid dry, of which the portion next the overfall rests upon masonry laid in mortar, while the portion farther from the overfall rests upon a timber platform. The end of the apron is protected by a line of sheet piling.

The gate-chamber is built of cut granite on a rubble stone foundation, and contains the iron gates necessary to turn the water into the aqueduct or the river.

The earth embankments contain core walls of rubble stone laid in cement mortar. A wing-wall of rubble masonry faced with cut granite is built where the earth embankment joins the masonry of the overfall and gate-house. In the earth embankments the upstream side was formed of the best material, or mixture of materials, to be found on the site, deposited in thin layers, wet and compacted by rolling; the downstream side was formed of gravel, to prevent wash in case of slight percolation through the dam.

Reservoir No. 1 has a muddy bottom and is apt to contain at the end of summer a large amount of organic matter. It is not used at such times for the supply of the city, but from it 1,500,000 U.S. gallons per day are wasted into Sudbury river, in compliance with the requirement of the act under which the water was taken.

Reservoir No. 2 is a narrow body of water stretching two miles up the Sudbury-river valley and crossing the Boston & Albany Railroad east of Ashland Station.

Dam No. 2 is in most respects similar to Dam No. 1. The middle portion of Dam No. 2, however, is founded on rock. Its masonry overflow is longer, to limit the line of flowage, and it is provided with a light iron bridge and stop planks.

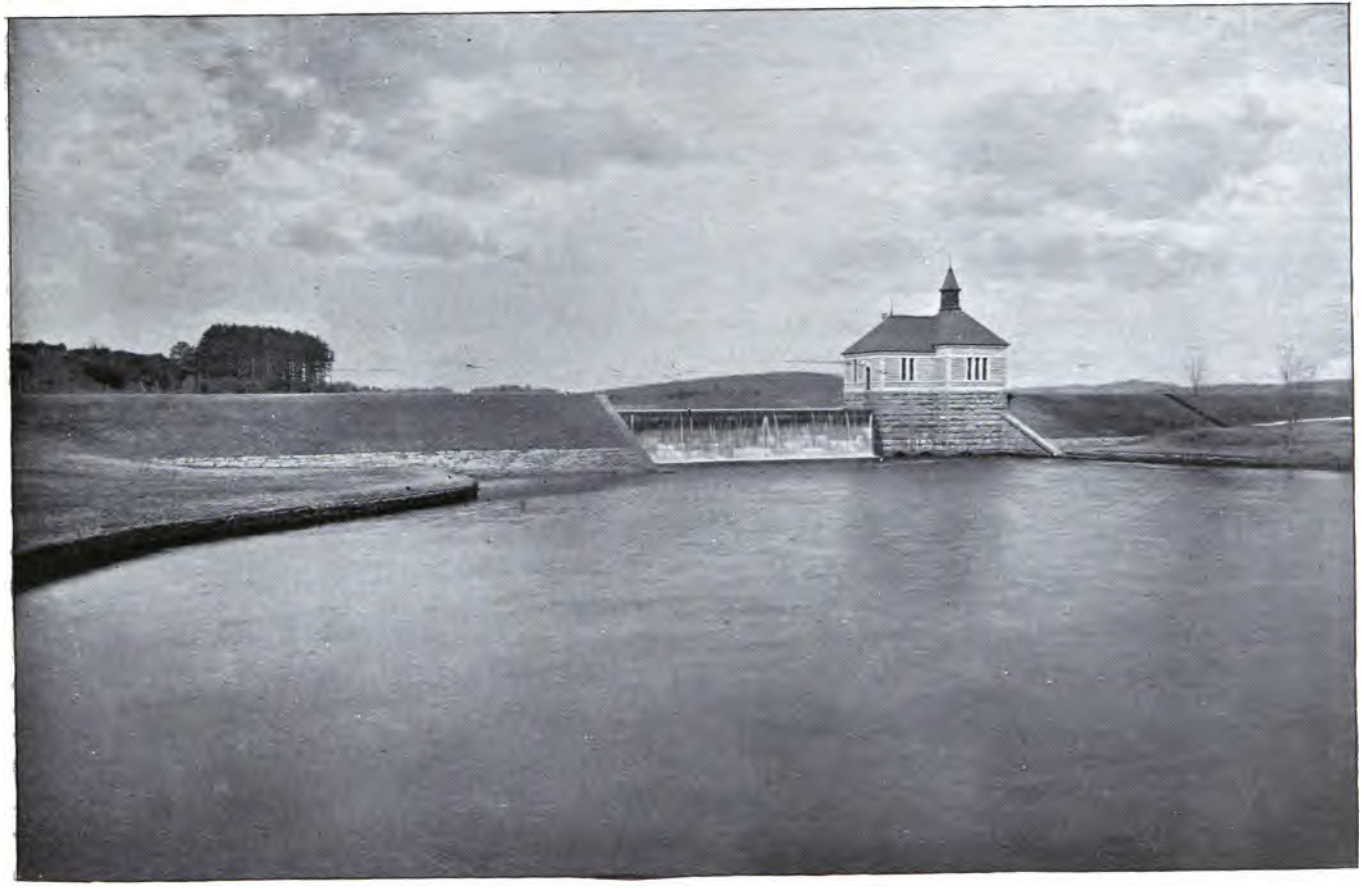
When Reservoir No. 2 was originally built, in 1878, the trees and bushes were cut off within the flow line, but loam and much perishable matter were left. In 1883 the water was drawn off and nearly 150,000 cubic yards of loam, muck, etc., was excavated from parts of the reservoir within 8 feet of the high-water line, and was used to fill up other shallow places, so that a minimum depth of 8 feet was secured. The banks were graded to a slope of 3 to 1, and were covered with coarse gravel, or in exposed places with paving or rip-rap, and thousands of stumps were removed. The total cost was $71,472.18.

Reservoir No. 3 extends from Dam No. 3 up Stony brook valley in a north-westerly direction nearly 2 miles, the head of it being near the Southborough line. It is separated into two portions by the line of the New York, New Haven, & Hartford Railroad (Old Colony system). It holds 1,080,000,000 U.S. gallons.

The dam is very similar to Dam No. 1. Its total length is 2,250 feet, but a large portion of this is only slightly raised above the original surface. In some parts of it the core wall has been carried down to depths of 20 or 30 feet.

The trees and bushes were cut off within the flow line in 1877, but the soil was left, and several years later the reservoir was improved on the same general lines already described under Dam 2.

Reservoir No. 4, one mile long and 167 acres area, is in the valley of Cold-spring brook, near Ashland. It consists of an earth embankment 60 feet high, 20 feet wide on top, and 1,800 feet long, in which is a concrete core wall about 8 feet thick at the bottom and 3 feet thick at the top,



DAM NO. 3.

DAM VI. — SHOWING WATER SIDE.

and nearly 100 feet high in the middle of the valley. At irregular intervals of 150 feet or more, buttresses 3 feet wide and 1 foot thick break the continuity on the water side. This core wall is carried down into bed rock. The concrete is mixed in the proportion of 1, 2, and 5, and the upstream face of the wall is very carefully plastered with neat cement. The embankment on the downstream side has a slope of 2½ horizontal to 1 vertical, and is covered with a foot of loam and turf. On the water side the slope is 1½ to 1, as far down as the berme, and 1.65 to 1 below the berme, and is protected by paving laid on broken stone or riprap. The masonry overfall is on the easterly side of the valley. It is one foot below high water, 30 feet in width, between side-walls of rubble masonry, and the waste water is allowed to descend to the bottom of the valley by a succession of heavily paved steps laid on concrete. Water is drawn from the reservoir by means of iron pipes passing through the embankment, controlled by gates in a gate-chamber of masonry adjacent to the concrete core wall. It is arranged that water can be drawn from different elevations by passages one above another. This reservoir was the first one to have all the soil removed from within its flow line. It cost $813,846.38, and about four years were occupied in its construction (1881–85).

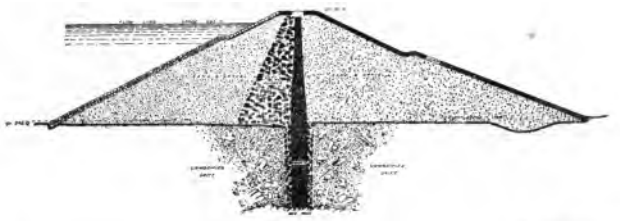
Reservoir No. 6, built in 1890–4, occupies two miles of the valley of Indian brook, and its dam is about three miles west of Ashland Station, on the Boston & Albany Railroad. It covers 185 acres, and is very similar to Reservoir No. 4.

On the embankment of Dam No. 6, which is 65 feet high, the slopes on the water side are 2 to 1, and the paving is continued to the very top. On the downstream side the slope is 2 to 1 down to a level 22 feet below the top of the dam. There a berme 6 feet wide is graded so as to carry the rainfall to five sod gutters placed at intervals down the lower portion of the embankment, which slopes 2½ to 1 to the bottom. There are at least two feet of loam under the sod.

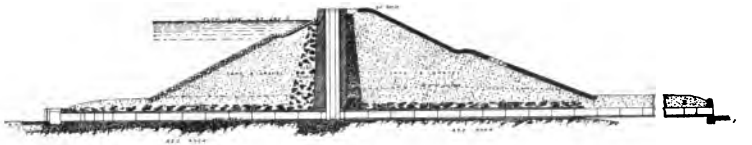
The most marked difference between Dam No. 4 and Dam No. 6 is in the arrangement of the discharge-pipes. One pipe is on each side of the valley, about half-way from the middle to the end of the dam, and there are two gate-chambers. On the south side of the valley the 36-inch discharge-pipe is to be connected at its inner end with a hinged pipe and float, so arranged that its mouth can be kept near the surface of the water, or at other elevations where the best quality may be found. The 48-inch pipe from the other gate-house discharges into the channel of the overflow. The 36-inch discharge-pipe is 16 feet above the bottom of the reservoir, and 37 feet below high-water mark. At about the level of its outlet, and immediately below the dam, there is a gravelly area well adapted for a filtration-field. It has accordingly been graded, in order that the water that comes through the pipe may be filtered by passing through the ground before entering the outlet stream. On the drainage area of Reservoir No. 6 there are large swamps which cause some color in its water; the greater part of the village of Hopkinton is included in the area. The site of the reservoir, like that of No. 4, was completely stripped. The cost of this reservoir was $910,300, and it is the best example of its kind to be seen on the Boston Water Works.

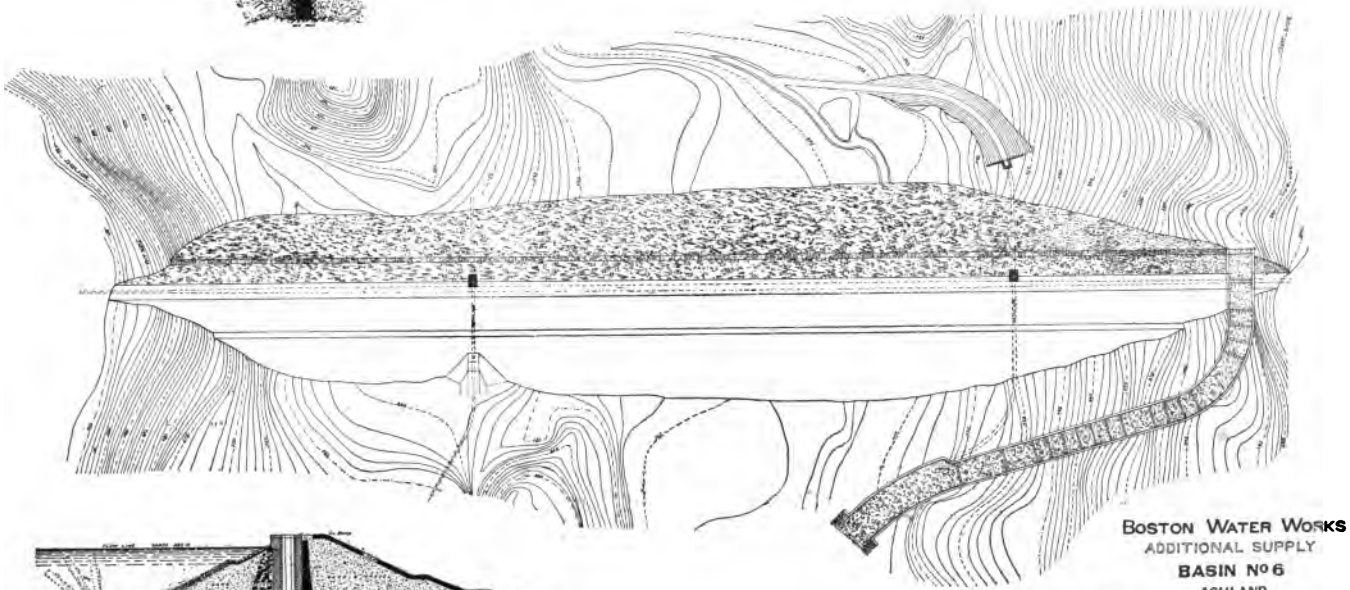
Whitehall Reservoir, acquired by the city in 1892, is at Woodville, about four miles from Westborough, and is of very different character from those numbered 4 and 6, which it approaches in capacity. Here originally was a small pond called Whitehall pond; across the stream which flowed from it, an inexpensive dam was built, many years ago, at a narrow gorge about three-fourths of a mile below the pond. This overflowed the old pond and nearly a square mile of surrounding territory, much of which was covered with trees. It is expected that the stumps will be removed, the bottom dredged, some of the shallow valleys at the sides filled up, and the depth increased 8 feet by building a new dam. The water-shed is 4.353 square miles in area, and the surface of the pond is 1 square mile in area.

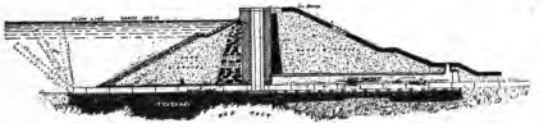
Section of Dam



Section of Dam at 48 inch outlet.







Section of Dam at 36 inch outlet.

Boston Water Works

Additional Supply

Basin No 6

Ashland

General Plan of Dam

Scale of Plan

Scale of Sections

Approved

William Jackson
City Engineer

Reservoir No. 5, the construction of which was begun in 1894, is to cover two square miles of what was mostly farming land. When completed it will be the largest artificial storage reservoir in New England. It will hold 7,400,000,000 U.S. gallons, which is nearly as much as all the other reservoirs of the Sudbury system put together. This dam is best reached by a walk of a mile from Fayville on the New York, New Haven, & Hartford Railroad (Northern Division, Old Colony system), or by carriage from Southborough, the next station, or by driving five miles from South Framingham.

The dam is nearly 2,000 feet long and 70 feet high above the bed of the stream; at each end it has an earth embankment similar to Dams Nos. 4 and 6, but differs conspicuously from them in its overfall, which is in the middle. This is a massive stone wall 60 feet high, 300 feet in length, and has its downstream side curved to guide the passage of water over it and to discharge it upon the rock in the bottom of the valley below. In Dam No. 5 there are wing-walls where the earth embankments join the masonry; the gate-chamber is built adjacent to the overfall with inlets at three different elevations near the top, middle, and bottom. The three 48-inch pipes that go through it descend and then turn up at the ends, discharging like a fountain, the outlet being surrounded by a masonry curb.

The soil and perishable matter is being removed from the site of Reservoir No. 5 as it was from Reservoirs Nos. 4 and 6.

A brook which drains the thickly settled part of Marlborough enters the north-west arm of Reservoir No. 5 near Marlborough Junction Railroad Station. Just above its point of discharge into the reservoir, filter-beds are building (in 1895) similar to those on Pegan brook at Lake Cochituate, as a protection against the danger of pollution from this stream.

It is now intended to bring the Metropolitan District supply from Nashua river into Reservoir No. 5, by the brook which enters its south-west arm; thence it is to go to

Boston and vicinity. This contingency was provided for in designing the reservoir.

Farm Pond. — In the original project of the Sudbury supply, Farm pond was to have been an important adjunct, serving as a settling and storage basin. With this in view a considerable part of the natural drainage from the shores of the pond was intercepted and diverted. Farm pond is very muddy and shallow, so that the bottom is apt to be stirred up by wave action in stormy weather. On account of the bad quality of the water resulting, Farm pond was cut off from the supply by the construction across it, in 1884–6, of a piece of aqueduct forming a connecting link between the gate-chambers at each end of the pond. By the upper of these the Sudbury river formerly entered the pond, and the gate-chamber at the lower end formed the entrance to the aqueduct leading to Chestnut Hill reservoir. The water is now conveyed through Farm pond without mingling with its waters. Any surplus in the pond can be wasted by its natural outlet into Sudbury river.

SANITARY CONSIDERATIONS.

It is of the first importance to provide adequate and suitable sewerage systems for the densely populated localities within the water-sheds supplying Boston with water; for example, the city of Marlborough, the most thickly settled portions of South Framingham, Natick, and Westborough, and the Reformatory Prison for Women at Sherborn.

The Boston Water Board has adopted the policy of encouraging the construction of works for the disposal of the sewage from such places, and of contributing towards the cost of such works for the sake of having sewage disposed of outside of the water-shed rather than within it. At Marlborough, works were projected for disposing of the sewage within the water-shed, and were changed so as to convey it a longer distance to a suitable place outside the water-shed,

FARM POND — SUDBURY AQUEDUCT.

and Boston paid $62,000 towards the expense. The works went into operation in 1892.

Boston paid $25,000 to the town of Westborough on account of the construction of sewerage works discharging near the Assabet river outside of the Sudbury water-shed.

A sewerage system for Natick has been planned and will soon be built, towards which Boston has offered to contribute.

The sewerage system of South Framingham, with which the Sherborn prison is connected, has been in successful operation for several years, and the city of Boston has contributed $31,000 towards its cost.

As to minor dangers threatening the purity of the streams, as from farm-houses and detached manufacturing establishments upon the water-shed, the law is explicit in forbidding any pollution. A small force of inspectors is maintained to guard against any infractions of the law, and to take special precautions in case of any nuisance or of the outbreak of disease the germs of which could possibly infect the water. The city of Boston has taken possession of narrow strips of land along the banks of some of the streams where there was risk of contamination.

Examination of Quality. — A constant watch is kept upon the quality of the water. Samples from the different reservoirs are collected every week, and systematic chemical analyses and biological examinations are made and tabulated, and from knowledge of the varying conditions in the different reservoirs valuable assistance is obtained for judging at what time it is best to draw from each, and at what time it is best to shut one off and let the water get the benefit of longer storage. For the biological work a small wooden building was specially built in 1889 on the grounds of the Chestnut Hill reservoir.

Extended experimental studies have been made from 1890 to 1894 on the filtration of water by various methods; these experiments also have been conducted at Chestnut Hill reservoir.

Averages of Monthly Analyses, January 1 to December 31, 1894, by Thomas M. Drown, M.D.

PARTS IN 100,000.

LOCALITY.	Color.	RESIDUE ON EVAPORATION.			Chlorine.	NITROGEN.					Oxygen Consumed.	Hardness.	Iron.	REMARKS.
		Total.	Loss on Ignition.	Fixed.		Albuminoid Ammonia.		Free Ammonia.	As Nitrites.	As Nitrates.				
						Unfiltered.	Filtered.							
Reservoir No, 2, influent	1.31	4.67	2.17	2.51	0.34	.0231	.0210	.0007	.0001	.0059	1.0566	1.2	.0173	
Reservoir No. 2, near outlet	1.12	4.36	2.05	2.31	0.33	.0216	.0192	.0008	.0000	.0057	0.9268	1.3	.0205	
Reservoir No. 3, influent	1.31	6.41	2.64	3.77	0.49	[1] .0302	.0249	.0023	.0001	.0151	1.0533	2.0	.0237	[1] Swamps flooded.
Reservoir No. 3, near outlet	0.96	5.48	2.20	3.28	0.41	.0265	.0231	.0018	.0001	.0105	0.8692	1.9	.0152	
Reservoir No. 4, influent	1.44	4.93	2.42	2.52	0.32	.0237	.0214	.0006	.0000	.0042	1.2054	1.3	.0146	
Reservoir No. 4, near outlet	.81	4.14	1.86	2.27	0.29	.0212	.0189	.0025	.0001	.0043	0.8648	1.1	.0126	
Reservoir No. 6, influent	2.11	6.57	3.29	3.28	0.55	.0317	.0294	.0014	.0000	.0020	1.6692	1.6	.0255	
Reservoir No. 6, near outlet, surface . .	0.72	3.85	1.53	2.31	0.38	.0184	.0158	.0013	.0000	.0039	0.6945	1.1	.0165	Surface means 1 foot below surface.
Reservoir No. 6, near outlet, bottom . .	1.00	4.08	1.73	2.35	0.37	.0175	.0148	.0081	.0003	.0026	0.6724	1.1	.0575	
Lake Cochituate, gate-house	0.20	4.76	1.59	3.17	0.51	.0163	.0137	.0008	.0001	.0070	0.3699	2.0	.0077	
Service-pipe, Mass. Inst. Tech., Boston .	0.69	4.64	1.83	2.81	0.41	.0169	.0150	.0006	.0001	.0106	0.6295	1.7	.0147	
Mystic Lake	0.11	15.60	2.53	13.07	3.48	.0235	.0168	.0381	.0012	.0582	0.2608	5.2	.0099	

AQUEDUCTS.

The waters conveyed by the Sudbury and Cochituate conduits are usually mingled at Chestnut Hill reservoir. Occasionally Sudbury-river water is let out of its conduit at the waste-way where it crosses Course brook, a feeder of Lake Cochituate; thus it runs into the lake and may get to Boston by way of the Cochituate conduit. In this way surplus water from Sudbury river can be stored in Lake Cochituate, which has very large storage capacity relatively to its drainage area, and is not always filled in the spring by its own tributaries.

The Cochituate Aqueduct, 14.6 miles in length, is built of brick masonry laid in cement with the exception of its two tunnels and of the crossing of Charles river near Newton Lower Falls. It is egg-shaped, with the large end down, 5 feet wide by 6.33 feet high inside, and is 8 inches in thickness. The slope of the aqueduct is $3\frac{1}{6}$ inches per mile and its capacity is about 18,000,000 U.S. gallons per day. Owing to the facts that its section is thin, that it has no other support than the surrounding earth, and that water has for years been forced through it under a head, it has settled out of shape and cracked, but it is now in good repair. The embankments are 8 feet wide on top, with slopes of 2 to 1, and they are built 4 feet above the top of the brick-work.

One of the tunnels is in Newton, very near the present boundary line of Boston. It is 2,410 feet long. The other tunnel is in Brookline, very near the Brookline reservoir, and is 1,150 feet long. Concrete was laid in the bottom of the tunnels, and where necessary they were lined with brick.

At the Charles-river valley, instead of continuing the conduit on its regular grade, an inverted siphon of iron pipes is substituted, crossing the valley at a level 52 feet lower. Two 36-inch pipes and one 30-inch were originally laid, and in 1875 a 40-inch pipe was added. The pipes cross the

river on a bridge of hammered granite having three elliptical arches of 30 feet span and 7½ feet rise, and a width of 21 feet.

There are also 4 waste-weirs at different points along the line, and 1 ventilator at the Newton tunnel, and 10 culverts for the passage of surface drainage across the aqueduct line, all built of granite masonry.

The Sudbury Aqueduct between Farm pond and Chestnut Hill reservoir is 15.9 miles long, 9 feet wide, and 7.67 feet high inside, which is equivalent to a circle of 8½ feet diameter. It has a slope of 1 foot per mile, and a capacity when running full of 100,000,000 U.S. gallons per day. The upper portion from Dam No. 1 to and across Farm pond, 1.5 miles, has a slope of 2.323 feet per mile, and the interior dimensions are reduced to 7 feet wide by 6.88 high.

The conduit generally has a foundation of cement concrete with side walls of rubble stone masonry laid in cement mortar; the covering is a brick arch, and the sides and bottom are lined with brick. The exterior dimensions are varied according to the materials and position in which it is built. In wet, sandy trenches, a wooden platform was used as a support, and the drainage was so conducted as to avoid displacement of the light material. Across Farm pond, where there was deep mud and quicksand, the timber platform was supported on a foundation of piles around which gravel was filled so as to displace most of the mud. In peaty meadows the soft material was removed for nearly the whole width of the embankment and replaced by compact gravel, which was laid in water and in thin layers, and was left to settle a whole winter before the aqueduct was built upon it. In several places along the line very high embankments were successfully formed as support for the conduit, and the settlement has been generally not more than one-half inch in forty feet.

ECHO BRIDGE — SUDBURY AQUEDUCT.

Tunnels on the Line of the Sudbury Aqueduct.

			Feet long.
Rockland street	tunnel	in Natick . . .	1,754
Badger Hill	"	" . . .	1,646
Pleasant street	"	Newton Centre, about .	500
Beacon street	"	" " . .	4,635

It was at first thought that the roof of the last-mentioned tunnel, which is of the Roxbury conglomerate rock, would sustain itself permanently, but it has subsequently proved necessary to put in a concrete lining.[1]

Echo Bridge, at the Charles-river crossing, Newton Upper Falls, is the principal structure to be seen on the line of the aqueduct.

It is built of granite with a brick top, and is 79 feet above the bed of the river. It is 475 feet long, and consists of seven arches, of which the principal one, 129 feet span, is a light and beautiful arch springing from the rocky banks of the river and spanning its whole width. The name "Echo bridge" has been given to this work because of the echoes to be heard under the main arch, to which access is had by means of a staircase on the east bank. The high rocky bluffs on both sides of the river are covered with hemlocks, forming a most picturesque scene.

The other arches of the bridge are much smaller. On the west bank there is one segmental arch of 34 feet span, and on the east bank there are four semicircular arches of 37 feet span, and a segmental arch over Ellis street of 28 feet span.

The whole structure is built on conglomerate rock; it is 18 feet wide; but on the east bank of the river the rock supporting the abutment of the main arch was somewhat disintegrated, and the width of that abutment was gradually widened to 22 feet at the ground. The voussoirs of the

[1] Described in the transactions of the American Society of Civil Engineers, Vol. 31, p. 294. (March, 1894.)

large arch are five feet deep at the crown, increasing to 6 feet at the level of the ground.

The outer spandrel walls, 4 feet thick, are made of rubble work faced with ashlar. They are capped by a string course which extends the whole length of the bridge, forming a cornice. Above this are the brick walls at the sides of the conduit, 3.58 feet thick, capped with a stone coping that carries an iron fence. Inner spandrel walls of brick, 16 inches thick, carry flagging stones that support the bottom of the conduit. Between the walls underneath the conduit are galleries accessible for inspection and permitting the drainage of leakage water.

Waban Arches. — About five miles west of Echo bridge, in the southern part of Wellesley, the Waban bridge crosses the valley of Waban brook at its junction with Charles river. It has a total length of 536 feet, and consists of nine semicircular arches of 44.67 feet span. It is 18 feet wide and 48 feet above the bed of the brook. The piers were built on pile foundations; the arch stones are $2\frac{1}{2}$ feet deep. The upper portion of the bridge and the conduit are of the same construction as at Echo bridge, already described.

Rosemary Siphon, 1,800 feet long, crosses the valley of Rosemary brook, in Wellesley. It is composed of two 48-inch pipes, and provision has been made for adding another when required by the increasing quantity of water to be supplied. The pipes descend sharply at each side of the valley, and cross the brook about 46 feet below the grade line of the brick conduit. The brook passes under the pipes in a culvert of 10 feet span, and water can be discharged into the brook by blow-off gates on the pipes. At each end of this inverted siphon there is a large chamber of masonry, with an ornamental building over it, which forms the necessary connection between the pipes and the brick conduit.

Other Structures. — There are four waste-weirs and forty-two culverts on the line.

LOW SERVICE DISTRIBUTING RESERVOIRS.

Brookline Reservoir was expected, when designed, to be sufficient for the needs of Boston for a long time, and it continued for twenty years to be the principal distributing reservoir of the city. It is of irregular oval shape, formed out of a natural basin, whose banks rise generally to a considerable height. On the northerly side, however, there was no bank; consequently a puddled embankment was built to a height of about 26 feet. The area is about 23 acres, and the depth varies from 14 feet to 24 feet. The high-water line is at grade 125.00. The available capacity is 115,000,000 U.S. gallons. The inner slope of the reservoir is lined with a slope-wall of granite rubble 18 inches thick, rising to within 1 foot of the top of the bank. The upper gate-house, where the aqueduct enters the reservoir, is fitted with a flap-gate which closes and prevents water from escaping from the reservoir when the aqueduct is emptied. The building is of granite 12 feet square and 11 feet high and it has a stone roof. The principal gate-house is the lower one, at which is the beginning of the iron mains leading into Boston, with regulating gates and gauges. It is about 44 by 26 feet in plan, is set in the embankment, and has some architectural interest.

Minor Reservoirs. — Three small distributing reservoirs were built when the water-works were first inaugurated, two of which still remain in existence, though not high enough to give as much pressure as is now desired.

The South Boston distributing reservoir is at the east side of Telegraph Hill, South Boston. It is of approximately semicircular form, its greatest diameter being 370 feet, and it has a capacity of 7,500,000 U.S. gallons. It has a puddled embankment. The inner slope is laid with granite rubble, and the bottom paved with pebble-stones. It has been out of service since July 15, 1872, but is kept partially filled for use in special emergencies.

The East Boston distributing reservoir, on Eagle Hill, East Boston, is a somewhat similar structure, but is rectangular, 322 × 150 feet, and contains 5,500,000 U.S. gallons below a level 3 feet from the top.

Chestnut Hill Reservoir, at grade 125.00, the same level as the Brookline reservoir, is the principal receiving and distributing reservoir. It occupies a natural basin lying on both sides of the Cochituate aqueduct, about a mile from its termination in the Brookline reservoir. The slopes of the surrounding hills were adapted to form a large part of the bank of the reservoir, but for a length of about 2,000 feet on the south-east side an embankment with puddle wall had to be constructed, with a maximum height of about 35 feet. The cross embankment containing the Cochituate aqueduct divides the reservoir into two parts, the Bradlee basin on the east, having an area at high water of 87½ acres and a total capacity of 551,000,000 U.S. gallons, and the Lawrence basin on the west, having an area at high water of 37½ acres and a total capacity of 181,000,000 U.S. gallons. The two together thus contain about 731,000,000 U.S. gallons. The depth of water in the Bradlee basin is about 20 feet, and in Lawrence basin about 15 feet. The inner slope is paved with rubble 2½ feet thick, capped with granite blocks 3.35 feet below the top of the embankment. The paving has a slope of 2 horizontal to 1 vertical for a length of 19½ feet, measured on the slant; then there is a berme of 5 feet, and below it riprap with a slope of 3 to 1.

There is a gravel walk around both basins 8 feet wide, with 6 feet of sodding on each side of it. Outside of this walk is a driveway 60 feet wide, 2½ miles long. It is kept in the best condition, affords beautiful views of the basins and adjacent grounds, and is much frequented, forming really a part of the park system of the city.

On the embankment between the Lawrence basin and the Bradlee basin is the Intermediate Gate-house, by which

CHESTNUT HILL RESERVOIR.

water can be conducted from one basin to the other, or drawn from the Cochituate aqueduct into either.

There is also a small gate-house at the north-west side of the Lawrence basin for admission of water from the Cochituate aqueduct.

The Terminal Gate-chamber of the Sudbury aqueduct is on the south-west side of Chestnut Hill reservoir, nearly on a line with the intermediate embankment. It is a fine-hammered granite building 49 × 27 feet. From this chamber the Sudbury-river water can be drawn by separate pipes into the Lawrence basin, into the Bradlee basin, into the Cochituate aqueduct, by which it may go to the Brookline reservoir, or into the mains as they start from Chestnut Hill reservoir toward Boston, the last being by means of a line of 48-inch iron pipes laid around the south side of the Bradlee basin, so that the water need not enter Chestnut Hill reservoir.

The Effluent Gate-house is at the east side of the Bradlee basin. It is built with four separate compartments for four lines of 48-inch pipes, of which two are already laid. Each compartment has places for stop-planks, screens, hydraulic sluice-gates, and an open well in front of the pipe. Stop-cocks are also placed in the pipes.

From Brookline reservoir and Chestnut Hill reservoir the distribution is by gravity on the low service, which constitutes more than three-fourths of the whole, but nearly a quarter is pumped from Chestnut Hill reservoir for the high service.

HIGH SERVICE.

There were temporary high-service works for parts of the city beginning in 1870. They included the Roxbury standpipe and later the Parker Hill reservoir.

In the present high-service system, water is pumped from Chestnut Hill reservoir to Fisher Hill reservoir, the principal high-service reservoir, about a mile distant from Chestnut Hill reservoir and 116 feet higher, or at grade 241. From

Fisher Hill, mains connect with Parker Hill reservoir, 20 feet lower, and nearer the heart of the city. From these two reservoirs a network of separate mains extends into the different portions of the city.

There are also pumping works on a small scale for small districts in West Roxbury and East Boston.

Pumping-Station. — The principal pumping-station is on the southerly side of Chestnut Hill reservoir adjoining the circuit line of the Boston & Albany Railroad. This makes it convenient for the delivery of coal. The buildings are an imposing group, built of Milford granite with heavy trimmings of Longmeadow freestone. They consist of an engine-room 85 × 65 feet, with a basement, a boiler-room 80 × 56 feet, a coal-room 65 × 62 feet, connected with the boiler-room by an extension 44 × 20 feet; also a screen and connection chamber.

The chimney is located in the extension of the coal-house. It is 150 feet in height above the floor of the boiler-room, and the foundation extends to a depth of 26 feet.

There are three pump-wells in the basement of the engine-house; two of them are each 18 × 10 feet and 16 feet deep; the third is 21 × 10 feet and 16 feet deep. These wells are connected with the conduit by gateways, which are controlled by 3 feet × 3 feet iron sluice-gates.

Pumps. — The pumping machinery consists of a triple expansion vertical engine designed by E. D. Leavitt and built by the Quintard Iron Works, and a pair of Gaskill horizontal compound engines built by the Holly Company.

The Leavitt engine, standing between the two Gaskills, is one of the most remarkable in existence, in respect of duty and workmanship. Its three cylinders are 13.7 inches, 24.375 inches, and 39 inches in diameter. The cylinders are vertical and inverted. The steam and exhaust valves are gridiron slides worked by cams on a horizontal shaft

HIGH-SERVICE PUMPING-STATION — CHESTNUT HILL RESERVOIR.

which derives its motion by means of gearing from the crank-shaft. Motion is transmitted from crossheads by links, to beams or rockers carried in pedestals on engine bedplate. From these beams the connecting rods work off in one direction, and the pump links in the opposite direction, but inclined at an angle of about 30 degrees from the horizontal. The leverage of the various pins in the beams is such that the stroke, which is 6 feet in the case of the steam pistons, is reduced to 4 feet for the pump plungers. The placing of the pumps at one side of the engine was occasioned by the requirements of space to be occupied in the engine-room. The crank-shaft has three cranks at angles of 120 degrees. Between two of them the shaft carries a flywheel, and between the other two the gear for driving the cam-shaft.

High speed is made possible by the use of the Riedler valve construction. Each end of each pump has one suction and one delivery valve, consisting of a number of rigidly connected rings covering annular openings in the valve seats. The lift of the valve is practically instantaneous, and the closing of the valve is positive, it being actuated by a wrist motion similar to the Corliss steam-valve gear. The normal speed of the engine is 50 revolutions per minute, at which speed the pumping capacity is 20,000,000 U.S. gallons in 24 hours. The duty is expected to be as high as 145,000,000 foot pounds.

There is a Belpaire fire-box boiler for the Leavitt high-duty engine, 34 feet 4 inches long, 7 feet 6 inches internal diameter, with plates $\frac{8}{10}$ inch in thickness, with two separate furnaces and a common combustion chamber. It is made to carry a working pressure of 185 pounds per square inch. There are 201 tubes 3 inches diameter, 16 feet long, providing 3,000 square feet of heating surface.

In the Gaskill engines the high-pressure cylinders are 21 inches in diameter, the low-pressure cylinders 42 inches in diameter, the water-plungers 25 inches in diameter, and all have a stroke of 36 inches. The plunger displacement

is 302 gallons per revolution, and a speed of about 18.5 revolutions per minute gives the guaranteed capacity of 8,000,000 gallons per twenty-four hours.

Steam is furnished by two horizontal tubular steel boilers, 78 inches in diameter and 18 feet 5 inches long. The shells are $\frac{7}{16}$ inch thick, and each boiler contains 151 tubes 3 inches in diameter. Each boiler contains 2,171 square feet of heating surface and 49 square feet of grate area.

Fisher Hill Reservoir, in Brookline, is rectangular in plan, 500 × 295 feet measured on the top of the inner slope and 423 × 218 feet at the foot of the slope. The area of the water surface is 3.14 acres at high water, which is at grade 241. The capacity is 15,500,000 of U.S. gallons above grade 223, the foot of the slope. The reservoir, 18 feet deep, is partly in excavation and partly in embankment. The embankment is 20 feet wide on top, with outside slopes of 2 horizontal to 1 vertical, and inside slopes of $1\frac{3}{4}$ to 1. The inside slope is covered to above the high-water line with a layer of puddle 2 feet thick. The lower portion of this, up to grade 235, is covered with 9 inches of Portland cement concrete. Above grade 235 the clay puddle is stepped back so as to be well within the embankment, and the slope is faced with paving of Roxbury stone 15 inches thick laid dry on a bed of broken stone generally 1 foot thick. To prevent any slipping of the puddle or paving a footing of American cement concrete is placed at the toe of the slope. The bottom of the reservoir is covered with puddle 2 feet thick, made from brick clay and selected material from the excavation, generally in the proportion of one part clay and five parts of the excavated material, which is clayey gravel. For a distance of 10 feet from the foot of the slope the bottom is covered with a layer of Portland cement concrete 6 inches thick.

The gate-chamber is about 21 × 20 feet inside, with walls of granite masonry $5\frac{1}{2}$ feet thick at the bottom and $3\frac{1}{2}$ at the top. There is a concrete foundation 2 feet thick

FISHER HILL RESERVOIR.

under the whole chamber. Below this foundation are three cut-off walls of concrete 2 feet deep and 2 feet wide, extending across parallel with the middle line of the embankment. A brick division wall with sluice-gate at the bottom and stop-planks above prevents the reservoir from being emptied in case of a break in the force main. By means of two sluice-gates in the effluent chamber water can be taken from different depths. By closing the gates in the effluent chamber the water entering the reservoir can be made to pass over a weir, by which the water delivered by the pumps can be measured; otherwise it passes through a pipe to the centre of the reservoir.

	Cost.
Reservoir proper	$75,967 27
Sluice-gates, etc.	1,215 00
Gate-house	8,912 00
Engineering and miscellaneous . . .	12,999 08
Land	92,042 00
Total	$191,135 35

Parker Hill Reservoir was built in 1873–4, and was used for many years as the principal high-service reservoir, before the pumps were moved from Roxbury to Chestnut Hill reservoir. It is almost three miles south-west of the State House, near the summit of Parker Hill, which is the highest hill within that distance of the heart of the city, and commands a fine view of the city and harbor. The reservoir is approximately rectangular, being about 290 feet × 225 feet on the inside of the coping. The area of the water surface at high water is 1.47 acres. The depth in the centre is 24 feet. Its capacity down to a level of 2½ feet above the bottom of the outlet pipe is 7,200,000 U.S. gallons. H.W. is at grade 219.00.

It is built partly in excavation and partly in embankment. The natural soil was a hard clay gravel nearly impervious to

water; the bottom of the reservoir is lined with 2 feet of puddle made of material found in the excavation. The inner slopes of the reservoir, $1\frac{1}{2}$ horizontal to 1 vertical, have a lining of 4 feet in total thickness, consisting of 2 feet of clay puddle, 8 inches of broken stone, and 16 inches of Roxbury stone paving. At the top of the embankment there is a granite flagging 1 foot thick and 5 feet wide, serving as coping for the slope wall and as a walk around the reservoir. The outer slope is $1\frac{3}{4}$ to 1, and is covered with turf.

The gate-house is nearly in the middle of the south side. It has a heavy concrete foundation, and walls of granite rubble masonry laid in cement mortar, about 6 feet thick at the bottom, and about 3 feet at the top. It is divided by cross-walls into three departments, — the outlet chamber, the inlet chamber, and the drain chamber.

The arrangement is such that water can be drawn from any elevation in the reservoir, or can pass through the gate-chamber without entering the reservoir.

Cost.

Reservoir proper	$98,765 00
Superstructure, gates, engineering, etc. .	7,349 90
Land	99,678 91
Total	$205,793 81

West Roxbury High Service. — The highest land within the city limits is Bellevue Hill, in West Roxbury, whose summit is at grade 331, or 90 feet above high water in Fisher Hill reservoir. There are about 100 acres of land above grade 200, and 1,500 acres above grade 170.

The population of these elevated districts will for many years be comparatively small, and it would not be advisable to pump the whole of the water used in the high service to a height adequate to supply these extremely high points. The alternative was to build a separate system on a small scale.

The plan adopted was designed to supply the territory above grade 170. This was accomplished in 1886, by building a small pumping-station at the corner of Washington and Metropolitan avenues, in Roslindale, containing two Knowles' pumps, each with a capacity of 400,000 gallons per 24 hours, and two upright boilers, 42 inches in diameter, containing 85 2-inch tubes 6 feet long. A 12-inch force main, 4,000 feet long, connects the pumps with a wrought-iron tank, 24 feet in diameter and 40 feet high, on the summit of Bellevue Hill. This tank holds 125,000 gallons when filled to within 3 feet of the top. The tank is located on a lot of land that was given to the city of Boston for park purposes, and as it is the highest land within the limits of the city, an unusually fine view is presented on all sides. An appropriate observatory tower has been built over the tank, which prevents all trouble from ice. Top of tank is at grade 366.30.

Breed's Island High Service. — Breed's island is a part of East Boston too high to be supplied by the low service. In 1889 an independent high service on a small scale was established, consisting of a brick pumping-station on Condor street, at the foot of Brooks street, from which water is pumped through 11,000 feet of 12-inch force main to the summit of Breed's Hill, where it enters a tank 24 feet in diameter and 40 feet high, with its top at grade 194.40. A tower like the Bellevue Hill tower has been built over it.

Pumping into East Boston Reservoir. — As the ordinary pressure upon the low-service mains is insufficient for East Boston, pumping has been resorted to, beginning in 1880. The pumps are now situated in the Condor-street pumping-station. They work against a check-valve with a by-pass, placed in the 12-inch main leading to the reservoir. The lever arm of the by-pass is weighted so as to give an additional pressure upon the East Boston distributing pipes of about 20 pounds while the pumping is going on. The surplus

goes through the by-pass into the reservoir, which maintains the supply at a low pressure after the pumping stops, as at night.

Roxbury Stand-pipe. — The stand-pipe built in 1870 occupies the site of an old earthwork of the Revolutionary war. It consists of an iron shell 5 feet in diameter and 80 feet in height, enclosed in a handsome circular tower of brick-work with granite trimmings. There is a space 3 feet wide between the pipe and the brick wall, in which there is a spiral staircase leading to a lookout at the top, having a floor 3 feet below the top of the pipe. The exterior at the base is finished with four pediments with buttresses at the angles. The top is octagonal and has a steeple, making the total height 133 feet. The structure is painted white and is a conspicuous object, but is no longer in use. Before the high-service reservoirs were built, however, it played an important part in the distribution of the high-service water.

DISTRIBUTING PIPES.

Low Service. — The water of the Sudbury and Cochituate supplies is conveyed from Brookline and Chestnut Hill reservoirs to Boston by four cast-iron mains 30 inches, 36 inches, 40 inches, and 48 inches in diameter. The first three lead from Brookline reservoir, and the last from Chestnut Hill reservoir. Another 48-inch main leads from Chestnut Hill reservoir to the mains leading from Brookline reservoir, connecting with them a short distance from the Brookline reservoir gate-house. From these four principal mains branches are taken off for the supply of different sections. Pipes of 20 inches, 24 inches, and 30 inches diameter supply South Boston, Roxbury, and Dorchester. The northern portions of the city, Charlestown, and East Boston are supplied through three mains from 20 inches to 30 inches in diameter.

High Service. — Two force mains, one 30 inches and the other 36 inches, connect the pumping-station at Chestnut

Hill reservoir with Fisher Hill reservoir, and from the latter a 30-inch main, reducing to 24 inches, passes to Parker Hill reservoir. From the point of reduction a 24-inch main is taken off for the supply of West Roxbury; Brighton is supplied by a 16-inch main connected with the force mains not far from the pumping-station. From Parker Hill reservoir 20-inch and 24-inch mains extend to the heart of the city.

Smaller Pipes. — From these supply mains a network of 522 miles of pipes of 16 inches or less in diameter distribute the water. The general plan of the distribution system is to have 12-inch pipes at intervals of from 1,000 to 1,500 feet, with 6-inch and 8-inch pipes in the intermediate streets; but throughout the business part of the city 12-inch pipes are more frequent, and the district covered by the great fire of 1872 is now almost entirely piped with 16-inch, 12-inch, and 8-inch pipes. The proportion of small-sized pipes is less than in most of the large cities of the country. The large mains will supply the city with at least 100 cubic feet per second at a pressure of 40 pounds per square inch, which is an ample supply for 100 steam fire-engines. The mercantile section has a separate system for the sole purpose of supplying water under high pressure (80 to 90 pounds) to stand-pipe and sprinkler systems, which is available at all times, and which will not be affected by drafts from the hydrants. There are 6,217 hydrants in the Cochituate system, of four styles: the Boston, the Lowry, of which there are about 2,500, the Boston-Lowry, and the Post. The Lowry is generally placed directly over the supplying main and at the junction of connecting pipes, and is arranged to supply four engines. In the business portion of the city hydrants are generally from 150 to 200 feet apart, and from 250 to 300 feet in the residential quarters.

Pipes are laid 5 feet below the surface. Service pipes are of lead.

MYSTIC SUPPLY.

Mystic Lake in Arlington and Winchester, 6 miles northwest of Boston, was naturally below the level of high tide at the head of Mystic river. It was made a source of water-supply by building a dam and raising the upper Mystic lake to 7 feet above high tide, while the lower Mystic lake remains a tidal basin. The upper Mystic lake, or storage reservoir, is a mile long and nearly a third of a mile wide, with 87 feet maximum depth, having an area at high-water mark of 200 acres. It has a capacity of 380,000,000 U.S. gallons above a level 4.2 feet above the bottom of the aqueduct.

The dam is 11 feet above high-water mark in Boston harbor, and is an earth embankment 1,560 feet long, with a core wall mostly of puddle, but partly of concrete. The overfall consists of 5 piers and 2 abutments. Length over all, 80 feet. Distance between piers, 9 feet, closed by stop-planks.

From a gate-house at the easterly end of the dam the water is taken into an aqueduct, egg-shaped, 5 feet wide by 5 feet 8 inches high, and 7,453 feet long, terminating in a pipe-chamber on the north bank of Mystic river. From this pipe-chamber the water is carried under the river in two 36-inch pipes to the pump-well of the engine-house. Here there are three Worthington pumps, two of 5,000,000 gallons, and one of 8,000,000 gallons daily capacity. A Leavitt compound fly-wheel pump of 10,000,000 gallons daily capacity is now being erected at this station.

There are two 30-inch force mains, 3,277 feet long, connecting the pumping-station with the distributing reservoir.

Walnut Hill Reservoir is situated on Walnut hill, in Medford, near Tufts College. It is nearly a parallelogram in shape, 560 × 350 feet. Area, 4½ acres; depth, 26 feet; capacity, 26,244,415 gallons; H. W. 147.00. When full it has the appearance of one basin, but it is divided into two portions by a partition embankment. The inner slope of the reservoir is 1½ to 1. It is lined with 2 feet of puddle,

covered with 8 inches of brick-work to within 4½ feet of the top, where the lining is faced and coped with cut granite masonry. The bottom is puddled, and covered with 3 inches of concrete.

Water coming from the pumps is received into an influent chamber at the division wall, from which it can be discharged into the effluent chamber directly, or into either compartment of the reservoir.

Distribution. — From this reservoir Mystic water is distributed to Charlestown, now a part of Boston, and also by contract to the cities of Somerville, Chelsea, and Everett. These municipalities own their distributing systems and pay Boston for the water.

The original Mystic supply was distributed through cement-lined pipes, but these have been almost entirely replaced with cast iron in Charlestown since its annexation to Boston. There are 174 miles of pipes in the whole of the Mystic system, of which about 44 miles are in Charlestown. The whole number of hydrants is 1,446.

The Mystic Valley Sewer, built in 1877–8, is important in connection with the prevention of pollution of the Mystic water. It is in the towns of Woburn, Winchester, and Medford, near the line of the old Middlesex canal and of the Southern or Lowell Division of the Boston & Maine Railroad, and intercepts the drainage from a number of tanneries and houses. After passing through pumps, situated near Mystic lake, and receiving a chemical treatment, the sewage is discharged into the lower Mystic lake. A portion of this sewer in Woburn has recently been taken by the Commonwealth.

CONSUMPTION.

Deacon Waste Water Meters are used in connection with the inspections for the prevention of waste. They have a

hollow cone, small end up, through which the water flows, pressing upon a horizontal disk which is forced downward more or less according to the rate of flow. Connected with the spindle of the disk there is a pencil which makes a continuous record of the rate upon a sheet of paper moved by clockwork. They are adapted to measure large quantities of water. They are applied to the residential portion of the city, which is divided into 176 districts. When a district is separated from the rest by shutting gates, the Deacon meter is arranged to give a continuous record of the rate of flow into that district. This is done at night when the legitimate use of water is extremely small. If there is any waste, its locality can be detected by successively shutting off the house connections and gates on the pipes within the district and observing the effect produced upon the recorded rate of flow at the meter. If there is no waste, the trouble and expense of further inspection in that district is avoided. Many leaks have been discovered by this method and the average daily consumption diminished.

The cost of one of the Deacon meters set is about $300.

Consumption, Million Gallons per Day.

	Cochituate.	Mystic.		Cochituate.	Mystic.
1870	15.0	3.8	1887	29.9	7.6
1875	19.3	7.7	1888	33.3	8.3
1880	26.5	9.4	1889	32.1	7.8
1881	31.0	7.2	1890	33.9	8.3
1882	32.0	6.6	1891	37.7	9.1
1883	32.8	6.8	1892	41.3	9.8
1884	25.1	6.2	1893	47.6	11.2
1885	25.6	6.7	1894	46.6	10.3
1886	26.6	7.4			

Albany-street Yard. — The headquarters of the Eastern Division, which consists of the distribution system, has been since 1890 at the pipe yard, at 710 Albany street, in a building 41 × 215 feet, three stories in height. On the first floor are the offices of the superintendent and assistants, meter-testing room, machine-shop, engine-room, blacksmith-shop, and carpenter-shop. On the second floor is an office for clerks, a plumber-shop, and store-rooms. The third floor is devoted to storage purposes. Hydrants and gates used by the department are manufactured here.

SUMMARY OF COST OF SUDBURY AND COCHITUATE WORKS.

Cochituate supply:		
Lake Cochituate	$291,838 35	
Compensating reservoirs	66,859 80	
Land and water damages	248,827 34	
Engineering expenses to January 1, 1852	40,000 00	
Cochituate aqueduct	1,068,425 24	
		$1,715,950 73
Sudbury supply:		
Reservoir No. 1	$257,143 81	
" " 2	465,954 11	
" " 3	419,402 72	
" " 4	813,846 38	
" " 5, to Feb. 1, 1895,	279,818 86	
" " 6	910,301 18	
Whitehall pond	294,515 94	
Cedar swamp	14,695 21	
Work about Farm pond	17,297 94	
Road in Framingham	23,947 32	
Land damages, not otherwise specified	340,696 38	
Water damages	558,890 64	
Carried forward,	$4,396,510 49	$1,715,950 73

Brought forward,	$4,396,510 49	$1,715,950 73
Temporary connection with Lake Cochituate	75,611 73	
Investigations of Shawshine and Charles rivers, etc.	27,646 59	
Protection of supplies	177,514 39	
Engineering and engineering expenses	300,371 22	
Office expenses, travelling, etc.,	80,594 74	
Miscellaneous	35,282 93	
Conduit and connections at Chestnut-hill reservoir	3,082,661 95	
		8,176,194 04
Distributing reservoirs and distribution:		
Brookline reservoir	$200,077 21	
Beacon-hill " (net cost)	363,533 21	
Chestnut-hill "	2,277,042 93	
South Boston "	90,908 10	
East " "	66,103 09	
Parker-hill "	205,793 81	
Fisher-hill "	191,135 35	
Roxbury high service	103,829 53	
Brighton " "	7,745 00	
East Boston high service	30,208 12	
West Roxbury high service	22,346 56	
Chestnut-hill pumping-station	485,086 26	
Jamaica-pond aqueduct	88,417 20	
Pipe-yards and buildings	94,832 16	
Engineering expenses	57,873 58	
Distribution	9,406,891 01	
		13,691,823 12
Total cost of Sudbury and Cochituate works		$23,583,967 89

Cost of Mystic works to February 1, 1895:		
Land damages		$91,855 38
Dam	$17,167 26	
Grubbing at lake	9,393 26	
Lowering Mystic river	3,012 06	
		29,572 58
Conduit		129,714 30
Engine-house	$69,840 42	
Engine	161,499 55	
		231,339 97
Reservoir		141,856 26
Distribution		872,258 55
Buildings		18,603 05
Engineering, inspection, and salaries		53,216 27
Mystic-Valley sewer		83,608 70
Miscellaneous		24,446 88
Total cost of Mystic works		$1,676,471 94
Total cost of combined supplies		$25,260,439 83

Changes have been made in the construction account of the Cochituate works on the books of the department, to make the total correspond after February 1, 1895, as shown by the following statement:

Cost of construction to February 1, 1895, as per book account		$23,724,109 09
Add cost of new dam at Lake Cochituate, paid for from revenue		33,436 49
		$23,757,545 58
Deduct cost of temporary pumping plant at Lake Cochituate (now abandoned, and which was not properly chargeable to construction)	$23,577 69	
Credit by sale of Beacon-hill reservoir lot	[1]150,000 00	
		173,577 69
Cost of Sudbury and Cochituate works (as above),		$23,583,967 89

[1] This money was used for municipal purposes, and was not credited to water-works.

The total income of the works, at present, is about $2,000,000 yearly, which pays the interest, maintenance, and ordinary extension accounts. In other words, the Boston Water Works pays its expenses.

SUMMARY OF STATISTICS FOR 1894.

Boston Water Works, Suffolk County, Massachusetts, supplies also the cities of Somerville, Chelsea, and Everett.

Population by census of 1890:	
Boston	448,477
Chelsea	27,909
Somerville	40,152
Everett	11,068
Total	527,606
Date of construction:	
Cochituate Works	1848
Mystic "	1864

By whom owned. — City of Boston.

Sources of supply. — Lake Cochituate, Sudbury river, and Mystic lake.

Mode of supply. — Sixty-five per cent. from gravity works.
Thirty-five " " pumping "

Pumping.

	Cochituate.	Mystic.
Builder of pumping machinery	Holly Mfg. Co., and Quintard Iron Works.	H. R. Worthington.
Description of coal used:		
a Kind	Bituminous.	Bituminous.
c Size	Broken.	Broken.
e Price per gross ton, in bins	$4.40, $4.52	$4.45, $3.85, $3.75, $5.25
f Per cent. of ash	7.4	11.2

	COCHITUATE.	MYSTIC.
Coal consumed for year, in lbs.	4,637,660	8,763,800
Total pumpage for year, in gallons	3,795,830,595	3,751,418,700
Average dynamic head, in feet	126.18	148.62
Gallons pumped per lb. of coal	818.6	428.1
Duty in foot-lbs. per 100 lbs. of coal	86,459,300	53,057,500
Cost of pumping figured on pumping-station expenses,	$25,131.78	$32,924.65
Cost per million gallons raised to reservoir	$6.62	$8.777
Cost per million gallons raised one foot high	$0.052	$0.059

Consumption.

Estimated population	466,500	117,400
Estimated number of consumers	460,000	116,000
Total consumption, gallons,	16,994,405,800	3,752,970,500
Passed through meters	4,077,196,000	735,110,000
Percentage metered	24.0	19.6
Average daily consumption, gallons	46,560,000	10,282,100
Gallons per day, each inhabitant	99.8	87.6
Gallons per day, each consumer	101.2	88.6
Gallons per day to each tap,	679.2	442.1

Distribution.

	Cochituate.	Mystic.
Kind of pipe used,	Cast-Iron.	Cast-Iron, Wrought-Iron, and Cement.
Sizes	48 in. to 4 in.	30 in. to 3 in.
Extended, miles	12.75	6.9
Total now in use	572.80	173.7
Distribution-pipes less than 4-in. length, miles,	1.7	4.7
Hydrants added	175	148
Hydrants now in use	6,217	1,446
Stop-gates added	193	156
Stop-gates now in use	6,359	2,138

Services.

Kind of pipe used,	Lead.	Lead and Wrought-Iron.
Sizes	$\frac{5}{8}$ in. to 6 in.	$\frac{1}{2}$ in. to 4 in.
Extended, feet	49,841	18,436
Service-taps added	1,970	859
Total now in use	68,556	23,257
Meters added	291	33
Meters now in use	4,337	494
Motors and elevators in use	540	21

HOW TO SEE THE WORKS.

To visit the various places of interest on the water-works requires more than one day.

For a day's visit to the storage reservoirs, South Framingham on the Boston & Albany Railroad is the focal point; it is reached in thirty-five minutes from Boston. A morning express train now leaves Boston at 8.30. From South Framingham it is an hour's drive by way of Reservoirs No. 2, No. 1, and No. 3 to Dam No. 5. From this point it is an hour's drive by way of Fayville and across the Boston & Albany Railroad to Dam No. 6 or to Dam No. 4. A visit can be made to both, and return made to Boston by afternoon train from Ashland or South Framingham. Lake Cochituate is about three-fourths of an hour's drive from South Framingham in the opposite direction. Any single one of the storage reservoirs can be visited in half a day.

For a day's excursion to the works near Boston, one could begin with the office of the Eastern Division and pipe yard at 710 Albany street, and go thence by way of Parker Hill reservoir or Fisher Hill reservoir, or both of them, passing by Brookline reservoir, to Chestnut Hill reservoir. After viewing the grounds, the pumping machinery, laboratory, etc., a train can be taken from Reservoir station to Eliot station, or to Newton Upper Falls, which are within walking distance of Echo bridge, and return thence made by rail to Boston. In two or three hours a visit can be made to Chestnut Hill reservoir directly by the reservoir line of electric street cars, or by Boston & Albany Railroad train to Reservoir station.

Brookline reservoir is reached by a short walk from Brookline Hills Railroad station, or by taking the electric car marked Cypress street. Fisher Hill reservoir is on the hill just north of Brookline reservoir.

ORGANIZATION OF THE BOSTON WATER WORKS.

WATER BOARD.

THOS. F. DOHERTY, *Chairman.*
JOHN W. LEIGHTON.
CHARLES W. SMITH.

Secretary and Chief Clerk.

WALTER E. SWAN.

City Engineer and Engineer of the Board.

WILLIAM JACKSON.

Resident Engineer Additional Supply Works, and Superintendent Western Division.

DESMOND FITZGERALD.

Superintendent Eastern Division.

WILLIAM J. WELCH.

Superintendent Mystic Division.

EUGENE S. SULLIVAN.